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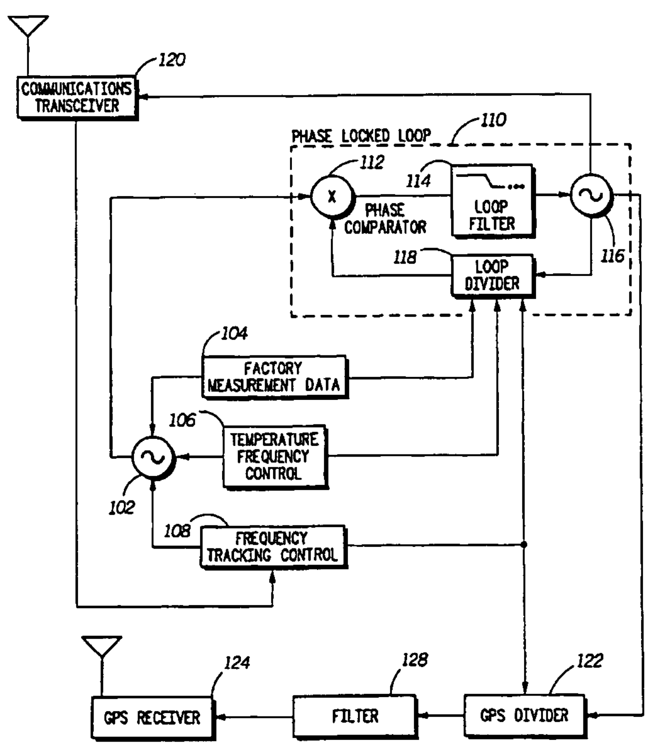
(54) Title: FREQUENCY MANAGEMENT IN A COMMUNICATIONS POSITIONING DEVICE



(57) Abstract: A frequency management scheme for a hybrid communications/positioning device, such as a cellular/GPS or other combined device, generates a local clock signal (102) for the communications portion of the device, using a crystal oscillator or other part. The oscillator output may be corrected by way of an automatic frequency control (AFC) circuit or software, to drive the frequency of that clock signal to a high accuracy. The base oscillator may be delivered to a phase locked loop (110) to drive a high-frequency clock for the cellular (120) or other communications portion of the hybrid device, which clock signal may also be frequency-converted to drive a GPS (124) or other positioning receiver. The extraction of a base GPS clock from the radio frequency reference eliminates the need for a second oscillator or synthesizer for that portion of the hybrid device. In embodiments, AFC tuning on the cellular clock may be omitted and the high frequency clock signal divided down for delivery to the GPS or other positioning receiver may be adjusted via a frequency prescaler, or other module.

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FREQUENCY MANAGEMENT IN A COMMUNICATIONS POSITIONING DEVICE

CROSS REFERENCE TO RELATED APPLICATION

This application relates to and claims priority from U.S. Provisional Application Serial No. 60/380,832 filed May 17, 2002, which application is incorporated by reference. This application is also related to the subject matter of U.S. Application Serial No. _____ entitled "SYSTEM AND METHOD FOR FREQUENCY MANAGEMENT IN A COMMUNICATIONS POSITIONING DEVICE", having docket no. CM03713J filed of even date with this application, having the same inventors as this application, being assigned to or under obligation of assignment to the same entity as this application, and which application is incorporated by reference in this application.

FIELD OF THE INVENTION

The invention relates to the field of communications, and more particularly to techniques for generating and managing precision frequency sources in cellular telephones or other communications devices having a positioning capability, such as Global Positioning System (GPS) or other location service.

BACKGROUND OF THE INVENTION

GPS receivers can be characterized by performance criteria such as acquisition and tracking time, which reflect the amount of processing necessary to detect and lock on to GPS satellite signals and hence the amount of time needed to begin accurately reporting a user's position. The acquisition, tracking, sensitivity and other performance parameters of GPS receivers can be affected by a variety of factors. Those factors include the precision with which frequency references for radio frequency detection and other purposes can be

generated and managed within the device. L1 GPS signals used for civilian coarse acquisition (C/A) purposes are broadcast at 1.575 GHz from the associated NAVSTAR satellites. Russian GLONASS satellites broadcast in a similar frequency range.

Handheld, vehicle-mounted, stationary and other GPS and other positioning receivers require frequency stability in their clocks generally in the range of a few parts per million or less to accurately derive Doppler and other data from those signals, and therefore triangulate a precise receiver position within a reasonable acquisition time.

Recently, market trends have developed toward GPS functionality combined with other communications services. Various wireless devices, such as cellular telephones, digital pagers, wireless personal digital assistants, 802.11a and other clients may all be combined with GPS location receivers for various applications.

However, the accuracy of reference clocks generally employed in cellular telephones and other communications devices may generally not be as great as that needed for useful GPS service, which as noted may require extended accuracy to within at least a few parts per million, down to tenths of 1 part per million or less for increased tracking performance. Cellular telephones on the other hand may contain uncompensated oscillators accurate to within only perhaps five to tens of parts per million, depending on implementation. Cellular devices may tolerate higher frequency variability in part because handsets or other devices may be able to derive a stable frequency reference from a base station or the wireless network, itself.

In the case of a GPS receiver combined with a cellular telephone for caller location service as mandated by the Federal Communications Commission, a cellular telephone's local crystal oscillator, tuned to 16.8 MHz or another base frequency, may for instance have a frequency variance of ± 30 ppm or more or less. A cellular handset's internal clock may therefore not be sufficient to drive GPS circuitry in a combined device for useful GPS

operation by itself. Temperature compensation circuits operating on ordinary crystal oscillators may improve the frequency reference to perhaps ± 5 ppm or so, although those types of parts may add to the cost of a relatively low-cost mobile device. Solutions such as supplying two corrected reference oscillators, one for GPS and one for cellular or other communications service at different frequencies, for instance, would not be likely to be economical in a combined device. Other problems exist.

SUMMARY OF THE INVENTION

The invention overcoming these and other problems in the art relates in one regard to a system and method for frequency management in a combined communications/positioning system, in which a stable base reference may be extracted for GPS purposes from a high-frequency reference used to drive the demodulation of signals on the communications side of the device. The invention in one regard thus allows both cellular and GPS circuits to be controlled from one source, without a need for a second oscillator in the GPS receiver portion of the device. According to the invention in one regard, the GPS circuitry may be driven by a signal from a phase locked loop generating a radio local oscillator for demodulation, downconversion or other communications operations, divided down to an appropriate base GPS frequency. The base oscillator driving the communications portion of the combined device may be corrected using for instance software temperature correction, hardware temperature correction, measurement of frequency bias at time of manufacture, automatic frequency control (AFC) or other techniques to establish accuracy in the communications portion of the device to ± 5 ppm or more or less. The GPS receiver component may consequently be driven with corresponding accuracy and therefore need not have a local oscillator of its own, while still achieving sufficient GPS performance at comparatively low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the accompanying drawings, in which like elements are referenced with like numbers, and in which:

Fig. 1 illustrates a frequency management architecture, according to an embodiment of the invention.

Fig. 2 illustrates a flowchart of frequency management processing, according to an embodiment of the invention.

Fig. 3 illustrates a frequency management architecture, according to an embodiment of the invention.

Fig. 4 illustrates a frequency management architecture, according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

An architecture in which a frequency management system according to the invention may be implemented is illustrated in Fig. 1, in which a combined communications/positioning device incorporates both GPS receiver 124 and a communications transceiver 120. The communications transceiver 120 of the combined device may be or include for instance a portable radio, cellular telephone, two-way or other pager, wireless modem, wireless personal digital assistant or other device that receives or transmits a radio, optical or other wireless communications signal.

The combined communications/positioning device as illustrated may contain a base oscillator 102 to provide a frequency reference to ultimately drive the communications transceiver 120. In embodiments base oscillator 102 may be a free-running, uncompensated reference part. The base frequency of the base oscillator 102 may be set to values compatible with cellular or other operation at 800/900 MHz, 1900 MHz or other

frequency ranges. The base oscillator 102 may for example be set to 16.8 MHz or other frequencies which may be multiplied to carrier ranges. An uncompensated crystal oscillator such as may be used to implement base oscillator 102 may by itself typically exhibit, for instance, a frequency deviation of ± 30 ppm or more or less.

In embodiments the output of base oscillator 102 may be processed or corrected using hardware, software or other techniques to improve frequency stability. Techniques to control base oscillator 102 may include, for instance, the use of factory measurement data 104 to compensate for detected frequency bias or offset in the manufactured part, and other artifacts. Factory measurement data 104 may in one regard be stored in the combined device and used to re-center the frequency of base oscillator 102 during operation, via software or otherwise. Other adjustments are possible. .

In embodiments, base oscillator 102 may likewise be controlled for frequency drift or other artifacts associated with varying temperature, using temperature frequency control module 106. Temperature frequency control module 106 may in embodiments be implemented using hardware, software, firmware, or combinations of the same to correct base oscillator 102.

Temperature frequency control module 106 may, for instance, in embodiments be combined in the base oscillator 102 using hardware components such as a temperature-controlled crystal oscillator (TCXO) or other hardware-corrected oscillator or reference part. A hardware TXCO may for instance exhibit a frequency accuracy of ± 5 ppm or more or less, depending on manufacturing, design or other factors.

In embodiments, temperature frequency control module 106 may be implemented using software control such as a temperature frequency control (TFC) or other algorithm, to sense and adjust frequency settings based for instance on temperature, power and other parameters.

The output of the base oscillator 102 may in embodiments be processed to further increase the accuracy of the frequency reference. As illustrated in Fig. 1, the frequency tracking control module 108 may apply correction to the base oscillator 102 to increase the accuracy of the frequency output. In embodiments, the frequency tracking control module 108 may be implemented in hardware, software, firmware or combinations of the same.

In embodiments, the frequency tracking control module 108 may be implemented in hardware, such as an automatic frequency control (AFC) circuit, of the superheterodyne, direct conversion or other type locking to a cellular or other carrier.

In embodiments, the frequency tracking control module 108 may be implemented in software algorithms, with correction instead for instance applied to a synthesizer or other associated part by programming logic or otherwise to achieve enhanced frequency precision.

In cellular or other communications networks, the accuracy of the frequency reference corrected by frequency tracking control module 108 may for instance reach ± 0.2 ppm or more or less, in part because cellular or other base stations may maintain accurate cesium or other clock references which may be broadcast over their communications channels. Frequency tracking control module 108 as illustrated may for instance communicate with and receive input from communications transceiver 120 to perform frequency tracking, by negative feedback or other techniques.

The frequency tracking control module 108 as illustrated may be applied to a phase locked loop 110 to drive operating frequencies for cellular or other communications or other operations. The phase locked loop 110 may include a phase comparator 112, to compare the phase of the base oscillator 102 with the phase of a high-frequency oscillator 116. High-frequency oscillator 116 may for instance be implemented as a voltage controlled high-frequency oscillator (VCO) generating frequencies, for instance, in the

800/900 MHz, 1900 MHz or other ranges for cellular or other operation. A loop filter 114 may low-pass filter the output of the phase comparator 112 to remove higher frequency artifacts or other noise.

The output of the loop filter 114 may in turn drive the high-frequency oscillator 116 to operating frequencies, which through the return provided by loop divider 118 completes a closed feedback loop to phase comparator 112. The phase of the high-frequency oscillator 116 is thereby locked to the phase of the base oscillator 102, so that the phase angle between them remains zero or approximately zero, or at a fixed or approximately fixed separation during operation.

The clock reference of the high-frequency oscillator 116 forms an output of the phase locked loop 110, which may in turn drive communications transceiver 120 to demodulate, downconvert and receive the wireless signals broadcast to the communications device, or perform other communications operations. In the embodiment illustrated in Fig. 1, each of the factory measurement data 104, temperature frequency control module 106 and frequency tracking control module 108 may likewise be in communication with loop divider 118 of phase locked loop 110, to correlate the adjustment of the output of phase locked loop 110 used to drive communications transceiver 120. For instance, in embodiments comparatively fine or other adjustments may be made to the ratio of loop divider 118, according to inputs from those corrective data or modules.

According to embodiments of the invention, the output of the phase locked loop 110 may also be used to drive GPS receiver 124 within the combined device. The GPS receiver 124 may consequently acquire and track GPS signals without the added costs of incorporating an additional local oscillator as well as associated automatic frequency control (AFC) or other signal processing circuitry or software to enhance the frequency reference for that portion of the combined device.

According to the embodiment illustrated in Fig. 1, a frequency reference output from phase locked loop 110 may be communicated to the GPS receiver 124 from the communications or other circuitry, without requiring a local oscillator apparatus in the GPS receiver 124. In this embodiment, the frequency reference derived from base oscillator 102 may for instance be divided by GPS divider 122 to a desired GPS frequency. GPS divider 122 as illustrated may likewise communicate with and receive input from the frequency tracking control module 108, to refine divider ratios or other adjust processing parameters. The output of GPS divider 122 may be communicated via filter 128 to remove noise, isolate demodulation frequencies or perform other signal conditioning. In embodiments the frequency division may for instance be performed using GPS divider 122 as a separate part, by an auxiliary synthesizer prescaler contained as part of a synthesizer or other part, or by other parts or software.

Since the accuracy of the output of the GPS divider 122 may track the accuracy of the base oscillator 102 treated by temperature, AFC, phase locked loop or other correction, this downconversion process may provide a reference signal to the GPS receiver 124 having an accuracy in embodiments of ± 5 ppm to .2ppm or more or less. This may eliminate any necessity to introduce a separate oscillator or a step-up phase locked loop in the GPS receiver 124 itself, reducing cost and increasing reliability in the resulting device.

Processing according to the invention in one regard is illustrated in Fig. 2. In step 202, processing begins. In step 204, base oscillator 102 may generate a 16.8 MHz or other clock reference signal, for communications or other purposes. In step 206, offset correction, if used, may be applied to center or otherwise correct the output of base oscillator 102, based on factory measurement data 104 or other data. In step 208, temperature correction using temperature frequency control module 106, if used, may be

applied to correct the output of base oscillator 102 to increase frequency accuracy or stability, for instance using software, circuitry, or other techniques.

In step 210, the output of the base oscillator 102 may be transmitted to the phase locked loop 110. In step 212, the phase locked loop 110 may lock the phase of high-frequency oscillator 116 to the phase of base oscillator 102. In step 214, the output of phase locked loop 110 may drive communications transceiver 120, for instance for cellular or other operation.

In step 216, the communications transceiver 120 may register or communicate with a cellular base station or other remote or other transceiver. In step 218, an AFC or other frequency tracking control may be performed on base oscillator 102, for instance by software, circuitry or other techniques.

In step 220, the output of phase locked loop 110 may be communicated to GPS divider 122, for instance to divide the incoming reference signal down to base frequencies which may be used to drive GPS operation, such as, for example, 24.5535 MHz or other frequencies.

In step 222, GPS divider 122 may generate an output reference signal according to the divide ratio, which in embodiments may be programmable or dynamically adjusted according to communications or other conditions. In other embodiments, the divide ratio may be hardwired, or be flashed or otherwise be set to remain relatively static.

In step 224, the output of GPS divider 122 may drive GPS receiver 124 for instance via filter 128 for radio frequency demodulation or other operations. In step 226, processing may end, repeat, or return to a prior processing point.

In an embodiment of the invention illustrated in Fig. 3, the output of base oscillator 102 may be communicated to the phase locked loop 110 omitting any frequency tracking control module, if that correction is not needed to achieve satisfactory accuracy in given

implementations. In such embodiments, the divide ratio of the GPS divider 122 may in cases be dynamically or otherwise adjusted, for instance in fine increments, to tune the resulting GPS frequency reference delivered to GPS receiver 124 without the benefit of an AFC or other circuit or algorithm. In this case, other compensation, such as that performed or effected by factory measurement data 104 and temperature frequency control module 106, may still be performed on base oscillator 102 as well as communicated to loop divider 118 or other parts of phase locked loop 110. Other types of correction or compensation to base oscillator 102, such as correction using factory measurement data 104 or other data, may also be applied, alone or in conjunction with temperature control or other techniques.

As noted, in this embodiment the divide ratio of the GPS divider 122 may for instance be adjusted to alter the clock reference delivered to the GPS receiver 124 by comparatively fine, or in implementations more or less coarse, amounts. The divide ratio may illustratively be an integer N, but floating point and other divide ratios are possible. The omission of frequency tracking correction or other types of compensation on base oscillator 102 in embodiments may depend, in part, on factors such as the frequency range of the communications transceiver 120, the detected offset of the base oscillator 102 during manufacture, the numerical precision of the divide ratio effected by GPS divider 122, or other factors.

In an embodiment illustrated in Fig. 4, the phase locked loop 110 may drive a synthesizer 126 or other part to generate other desired frequencies for cellular or other operation, rather than drive the communications transceiver 120 directly. According to this embodiment, the frequency reference may be programmed or scaled according to design needs, such as for instance for multi-band operation for cellular handsets, or other implementations. Likewise, in embodiments the GPS divider 122 may in turn drive a

synthesizer or other part to generate desired frequency ranges, rather than drive GPS receiver 124 directly. Other combinations are possible.

The foregoing description of the invention is illustrative, and variations in configuration and implementation will occur to persons skilled in the art. For instance, while the phase locked loop 110 locking high-frequency oscillator 116 to base oscillator 102 has been generally described in terms of a negative feedback topology including a comparator, loop filter, high-frequency oscillator and feedback divider, in embodiments the phase locking function may be implemented in other circuit configurations, by software algorithms, or other combinations of hardware and software.

Further, while the communications transceiver 120 and related circuitry has generally been described in terms of a cellular telephone equipped with positioning capability, other communications receivers or transceivers may be used. For instance, in embodiments a passive communications receiver rather than a two-way communications transceiver 120 may be implemented. Other receivers, transceivers, modems or other communications components may be used. For instance, in embodiments satellite-based communications receivers or transceivers, data links or other wired, wireless, optical and other interfaces or channels may be used. Likewise again, while the invention has generally been described in terms of a GPS device as the positioning receiver, other positioning systems or a combination of positioning systems may be used. Furthermore, while the invention has generally been described in terms of a pair of communications and positioning receivers, modems or elements, in embodiments three or more communications, positioning or other receivers, modems or other communications devices may be employed. The invention is accordingly intended to be limited only by the following claims.

CLAIMS

We claim:

1. A system for generating a frequency reference in a hybrid communications device, comprising:

a clock source in a communications portion of the hybrid communications device, the clock source generating a clock signal at a first frequency;

a frequency correction module, communicating with the clock source, the frequency correction module generating a clock signal at a corrected first frequency;

a frequency converter, the frequency converter communicating with the frequency correction module to receive the clock signal at the corrected first frequency and outputting a clock signal at a second frequency to operate a positioning receiver portion of the hybrid communications device to receive a wireless positioning signal.

2. A system according to claim 1, wherein the communications portion comprises at least one of a cellular telephone, a two-way pager and a network-enabled wireless communication device.

3. A system according to claim 1, wherein the clock source comprises an oscillator.

4. A system according to claim 3, wherein the clock source comprises a synthesizer.

5. A system according to claim 1, wherein the frequency correction module comprises a temperature frequency control module.

6. A system according to claim 5, wherein the temperature frequency control module comprises a temperature frequency control algorithm.

7. A system according to claim 5, wherein the temperature frequency control module comprises a temperature frequency control circuit.

8. A system according to claim 1, wherein the frequency correction module comprises an automatic frequency control module.

9. A system according to claim 8, wherein the automatic frequency control module comprises an automatic frequency control circuit.

10. A system according to claim 8, wherein the automatic frequency control module comprises an automatic frequency control algorithm.

11. A system according to claim 1, wherein the frequency correction module operates on manufacturing tolerance data.

12. A system according to claim 1, wherein the frequency converter comprises a frequency divider.

13. A system according to claim 1, wherein the positioning receiver portion comprises a global positioning system receiver.

14. A method for generating a frequency reference in a hybrid communications device, comprising:

generating a clock signal at a first frequency in a communications portion of the hybrid communications device;

generating a clock signal at a corrected first frequency based on the clock signal at the first frequency;

generating a clock signal at a second frequency based on the clock signal at the corrected first frequency to operate a positioning receiver portion of the hybrid communications device to receive a wireless positioning signal.

15. A method according to claim 14, wherein the communications portion comprises at least one of a cellular telephone, a two-way pager and a network-enabled wireless communication device.

16. A method according to claim 14, wherein the step of generating a clock signal at a first frequency comprises a step of exciting an oscillator.

17. A method according to claim 16, wherein the step of generating a clock signal at a first frequency comprises operating a synthesizer.

18. A method according to claim 14, wherein the step of generating a clock signal at a corrected first frequency comprises a step of applying a temperature frequency control module.

19. A method according to claim 18, wherein the step of applying a temperature frequency control module comprises a step of executing a temperature frequency control algorithm.

20. A method according to claim 18, wherein the step of applying a temperature frequency control module comprises a step of operating a temperature frequency control circuit.

21. A method according to claim 14, wherein the step of generating a clock signal at a corrected first frequency comprises operating an automatic frequency control module.

22. A method according to claim 21, wherein the step of operating an automatic frequency control module comprises a step of operating an automatic frequency control circuit.

23. A method according to claim 21, wherein the step of operating an automatic frequency control module comprises a step of executing an automatic frequency control algorithm.

24. A method according to claim 14, wherein the step of generating a clock signal at a corrected first frequency comprises a step of operating on manufacturing tolerance data.

25. A method according to claim 14, wherein the step of generating a clock signal at a second frequency comprises a step of operating a frequency divider.

26. A method according to claim 14, wherein the positioning receiver portion comprises a global positioning system receiver.

27. A system for generating a frequency reference in a hybrid communications device, comprising:

a clock source in a communications portion of the hybrid communications device, the clock source generating a clock signal at a first frequency;

a frequency converter, the frequency converter communicating with the clock source to receive the clock signal at the first frequency and outputting a clock signal at a second frequency, the second frequency being used to operate a positioning receiver portion of the hybrid communications device to receive a wireless positioning signal.

28. A system according to claim 27, wherein the communications portion comprises at least one of a cellular telephone, a two-way pager and a network-enabled wireless communication device.

29. A system according to claim 27, wherein the clock source comprises an oscillator.

30. A system according to claim 29, wherein the clock source comprises a synthesizer.

31. A system according to claim 27, wherein the frequency converter comprises a frequency divider.

32. A system according to claim 27, wherein the frequency converter comprises a prescaler.

33. A system according to claim 27, wherein the positioning receiver portion comprises a global positioning system receiver.

34. A method for generating a frequency reference in a hybrid communications device, comprising:

generating a clock signal at a first frequency in a communications portion of the hybrid communications device;

generating a clock signal at a second frequency based on the clock signal at the first frequency to operate a positioning receiver portion of the hybrid communications device to receive a wireless positioning signal.

35. A method according to claim 34, wherein the communications portion comprises at least one of a cellular telephone, a two-way pager and a network-enabled wireless communication device.

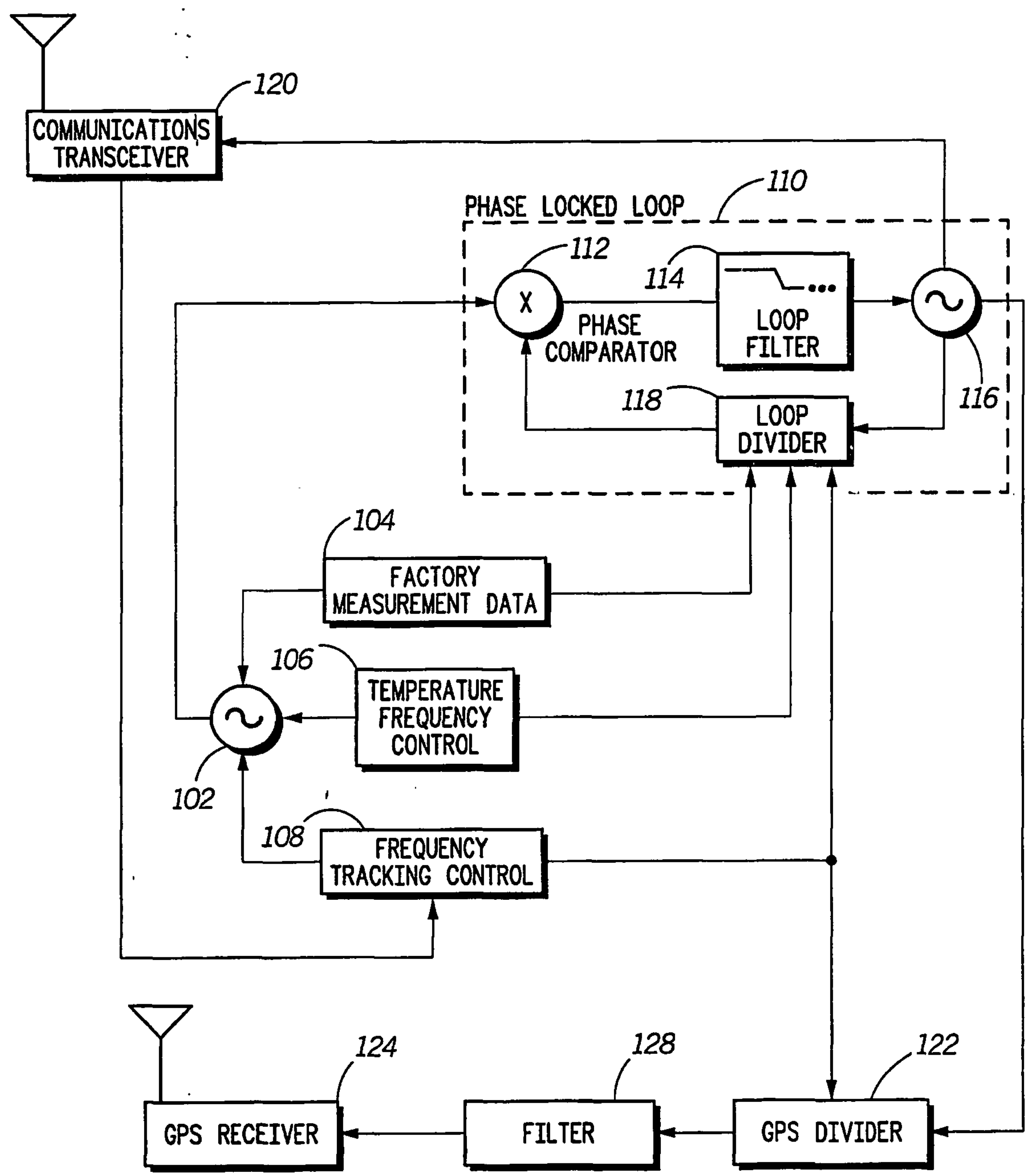
36. A method according to claim 34, wherein the step of generating a clock signal at a first frequency comprises a step of exciting an oscillator.

37. A method according to claim 36, wherein the step of generating a clock signal at a first frequency comprises a step of operating a synthesizer.

38. A method according to claim 34, wherein the step of generating a clock signal at a second frequency comprises a step of dividing the clock signal at the first frequency.

39. A method according to claim 38, wherein the step of generating a clock signal at a second frequency comprises a step of operating a prescaler.

40. A method according to claim 34, wherein the positioning receiver portion comprises a global positioning system receiver.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112
114
X
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LOOP FILTER
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LOOP DIVIDER
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104
FACTORY MEASUREMENT DATA
106
TEMPERATURE FREQUENCY CONTROL
102
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FREQUENCY TRACKING CONTROL
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GPS RECEIVER
128
FILTER
122
GPS DIVIDER

FIG. 1

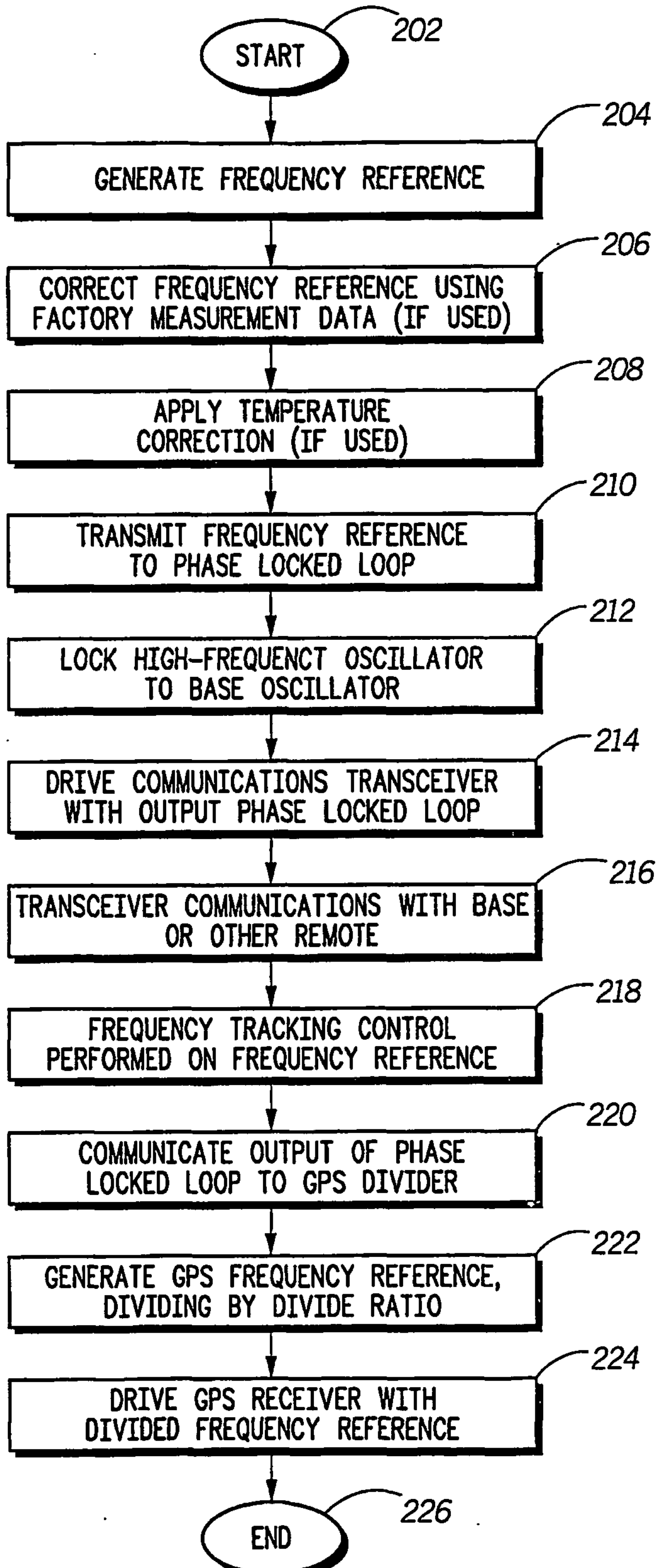
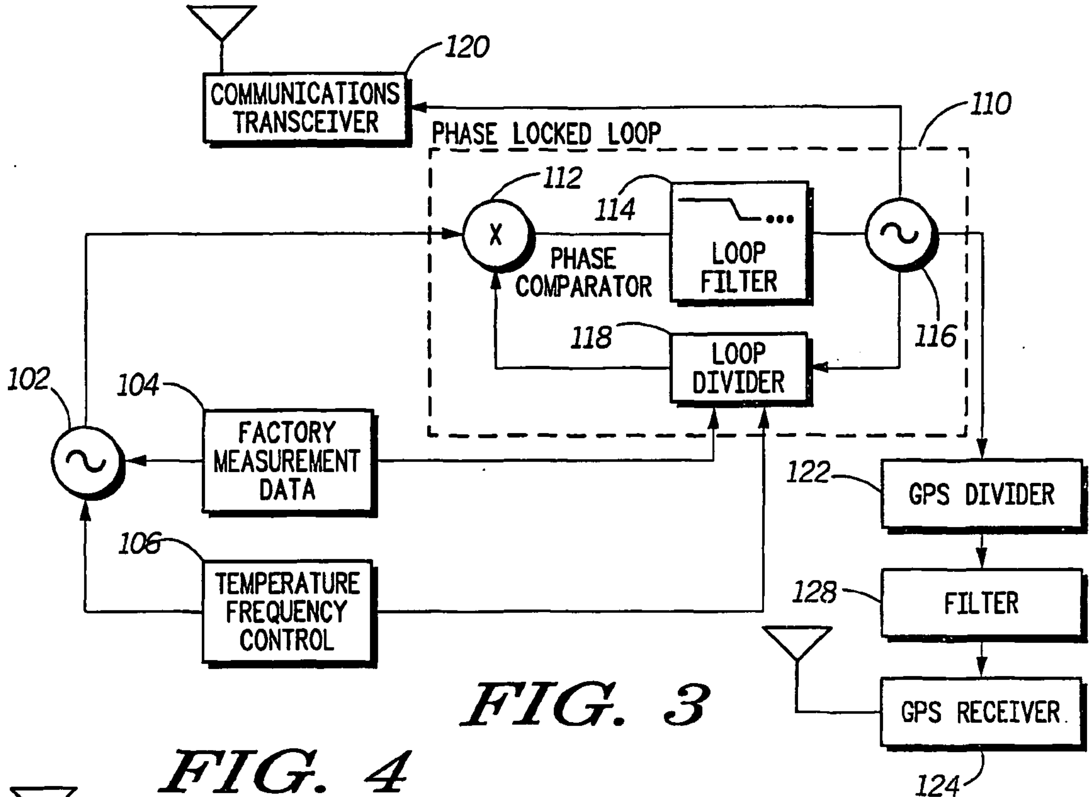

START
202
GENERATE FREQUENCY REFERENCE
204
CORRECT FREQUENCY REFERENCE USING FACTORY MEASUREMENT DATA (IF USED)
206
APPLY TEMPERATURE CORRECTION (IF USED)
208
TRANSMIT FREQUENCY REFERENCE TO PHASE LOCKED LOOP
210
LOCK HIGH-FREQUENCT OSCILLATOR TO BASE OSCILLATOR
212
DRIVE COMMUNICATIONS TRANSCEIVER WITH OUTPUT PHASE LOCKED LOOP
214
TRANSCEIVER COMMUNICATIONS WITH BASE OR OTHER REMOTE
216
FREQUENCY TRACKING CONTROL PERFORMED ON FREQUENCY REFERENCE
218
COMMUNICATE OUTPUT OF PHASE LOCKED LOOP TO GPS DIVIDER
220
GENERATE GPS FREQUENCY REFERENCE, DIVIDING BY DIVIDE RATIO
222
DRIVE GPS RECEIVER WITH DIVIDED FREQUENCY REFERENCE
224
END
226

FIG. 2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LOOP DIVIDER
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104
FACTORY MEASUREMENT DATA
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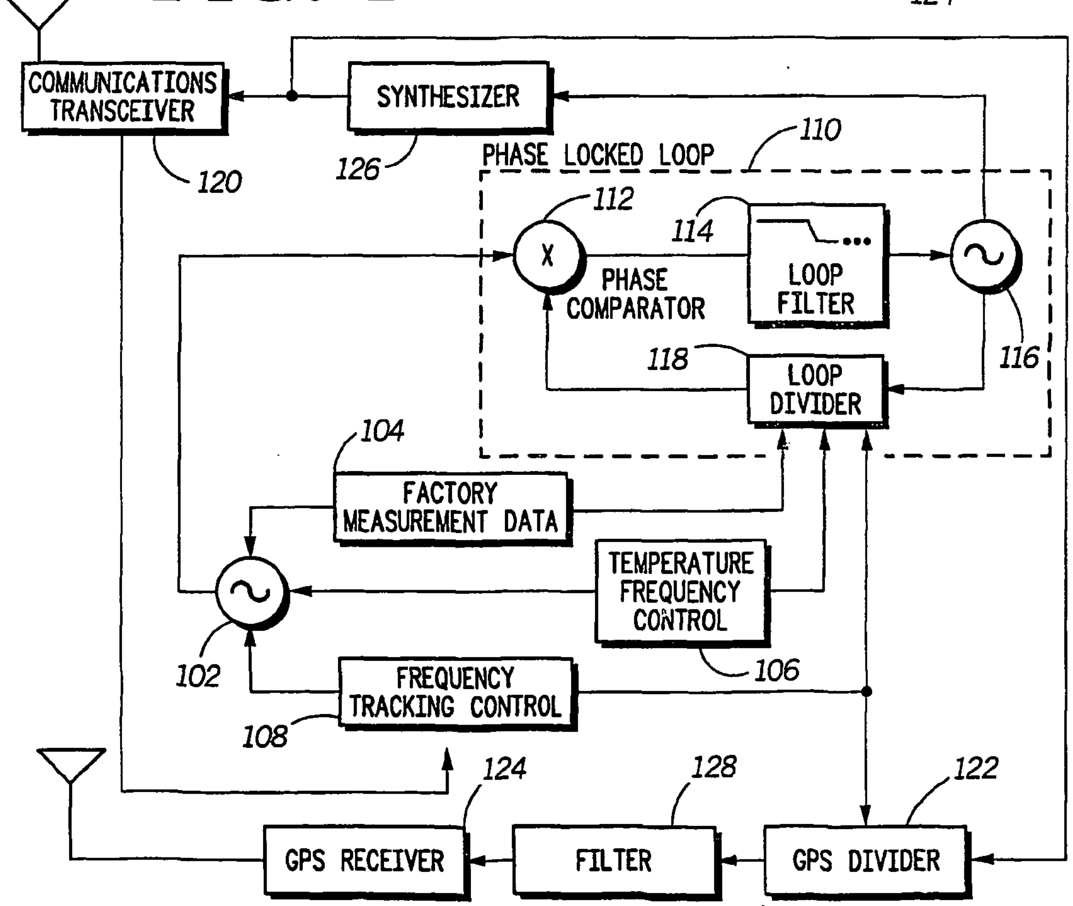
TEMPERATURE FREQUENCY CONTROL
122
GPS DIVIDER
128
FILTER
GPS RECEIVER
124

FIG. 3

FIG. 4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PHASE LOCKED LOOP
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LOOP FILTER
116
118
LOOP DIVIDER
104
FACTORY MEASUREMENT DATA
TEMPERATURE FREQUENCY CONTROL
106
102
FREQUENCY TRACKING CONTROL
108
124
128
122
GPS RECEIVER
FILTER
GPS DIVIDER

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/15561

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01S 5/02; H04B 7/185
US CL : 342/357.09, 357.1; 455/456

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 342/357.09, 357.1; 455/456

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,313,787 B1 (KING et al) 6 November 2001 (6/11/01) See entire document	1-40

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
19 August 2003 (19.08.2003)

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